

# Low 25(OH) vitamin D concentrations in international UK track and field athletes

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## Abstract

**Objective.** While it is recognised that vitamin D deficiency is common in the general population, there have been no studies in elite athletes in the UK. This observational study aimed to assess the 25 hydroxy-vitamin D (25(OH)D) status of elite athletes on the Great Britain track and field team.

**Methods.** A cross-sectional observational study was performed by analysing blood results from elite athletes on the British athletics team ( $N=63$ ; mean  $\pm$  standard deviation (SD) age  $24.9 \pm 4.2$  years). Athletes on the elite programme were offered blood tests through the winter and summer of 2009 and were eligible for inclusion in the study.

**Results.** Nineteen per cent ( $n=12$ ) of athletes in the current study can be classified as 25(OH)D deficient ( $<20$  mcg/l), while a further 29% ( $n=18$ ) can be classified as having insufficient serum 25(OH)D levels (20 - 30 mcg/l). Female sex (insufficient and deficient OH(D) prevalence 58%,  $n=18$ ) and dark skin (prevalence 65%,  $n=20$ ) were found to be independent predictors of serum 25(OH)D levels of  $<30$  mcg/l.

**Conclusion.** This study reveals a notable prevalence of low serum 25(OH)D levels in elite athletes and subsequent management of deficient athletes is likely to be of importance for athlete health. The impact of these results on athletic performance remains to be determined, and clinical trials to assess performance, particularly muscular performance, following correction of 25(OH)D status in deficient athletes are required.

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## Introduction

The epidemiology, clinical relevance and management of vitamin D deficiency are medical issues of both academic and public interest. The role of vitamin D in calcium regulation and bone health has been well established,<sup>1</sup> but recent evidence has identified associations between vitamin D deficiency and cardiovascular disease, diabetes, autoimmune disease, cancer of the prostate, breast and colon, as well as all-cause mortality.<sup>2-11</sup> As vitamin D has over 1 000 human genes

as direct targets, including skeletal muscle, heart, lungs and adrenal medulla,<sup>12,13</sup> there may be potentially significant consequences of vitamin D deficiency on athletic performance. However, there are very few publications about the prevalence of vitamin D deficiency in elite athletes or the effects of vitamin D deficiency on athletic performance. This is the first article regarding vitamin D status in elite track and field athletes.

Recent population studies have illustrated a significant prevalence of vitamin D deficiency in the general population,<sup>14-17</sup> and athletes also seem to be susceptible.<sup>18-20</sup> Serum 25(OH)D is widely accepted as a biomarker for vitamin D status.<sup>21</sup> While some debate persists as to optimal levels of 25(OH)D for health, it is generally accepted that levels of 20 - 30 mcg/l represent vitamin D insufficiency while levels below 20 mcg/l and 10 mcg/l are defined as deficient and severely deficient, respectively.<sup>10</sup>

Vitamin D is unique among nutrients in that almost all diets contain very little vitamin D and production primarily occurs in the skin, after exposure to ultraviolet B (UVB) sunlight.<sup>10,22</sup> Vitamin D cannot be effectively absorbed in the autumn and winter months in the UK because of the angle of the sun and atmospheric UVB absorption.<sup>23,24</sup> In the UK, reduced levels of 25(OH)D have been reported in a number of studies.<sup>25-28</sup> A large study of post-menopausal women reported 77% of women with 25(OH)D levels  $<28$  mcg/l.<sup>27</sup> Deficiencies have also been noted in 78% of patients attending a UK rheumatology clinic<sup>26</sup> and over 90% of an Asian cohort during a UK winter.<sup>25</sup>

It has been widely recognised that mean 25(OH)D levels are lower in dark-skinned individuals at all ages, with greater risk of insufficiency and deficiency.<sup>29-31</sup> This racial difference is primarily due to increased melanin pigmentation which reduces UVB absorption and subsequent vitamin D production.<sup>32</sup> However, with recent public health campaigns emphasising the dangers of sunlight exposure and advocating intensive sun-block cream use, reports have also found high insufficiency rates, of around 60%, in the UK Caucasian population, and those with the fairest skin type to be, in fact, most deficient.<sup>28</sup>

There have been very few publications on vitamin D status in athletes. Recently, in a study of 93 Middle Eastern male athletes, 91% were found to have a 25(OH)D level  $<20$  mcg/l.<sup>18</sup> A report of 18

elite gymnasts in Australia noted 9 to be vitamin D insufficient and a further 6 to be vitamin D deficient.<sup>19</sup> In a study of 9 - 15-year-old Finnish female athletes and non-athletes, 68% of all participants were found to have 25(OH)D levels <15 mcg/l.<sup>20</sup> However, a small study on seven competitive road cyclists in the south of France identified adequate mean 25(OH)D levels of 32.4 mcg/l.<sup>33</sup>

While there are limited data on the effects of vitamin D deficiency on performance in athletes, the potential relationship with fracture risk<sup>34-36</sup> and altered muscle function,<sup>37,38</sup> in addition to the additional pathological associations noted above, would suggest that the identification and subsequent treatment of vitamin D deficiency in athletes is prudent. In the UK, track and field athletes would appear to be at significant risk of deficiency given the UK latitude (51 - 54°N), the indoor training environment and the proportion of dark-skinned athletes in the elite UK Athletics Track and Field team. Therefore, the aim of this study was to assess

the 25(OH)D status of funded elite track and field athletes in the Great Britain team.

## Methods

### Participants

All elite athletes funded on the UK Athletics World Class Performance Plan and training at UK Athletics High Performance Athletics Centres (N=80) were offered 25(OH)D testing throughout the 2008 - 2009 season as part of a routine blood screening programme. Any athlete on this funded plan is considered to have the potential to win a medal at a World Championship or the Olympic Games. No athletes were taking high-dose vitamin D (>1 000 IU/day) supplementation in the 3 months prior to the study. Other vitamin or mineral supplementation, including calcium intake, was not recorded. The study group comprised all athletes who underwent the blood test between December 2008 and August 2009 (N=63) and completed informed written consent for the study.

### Data collection

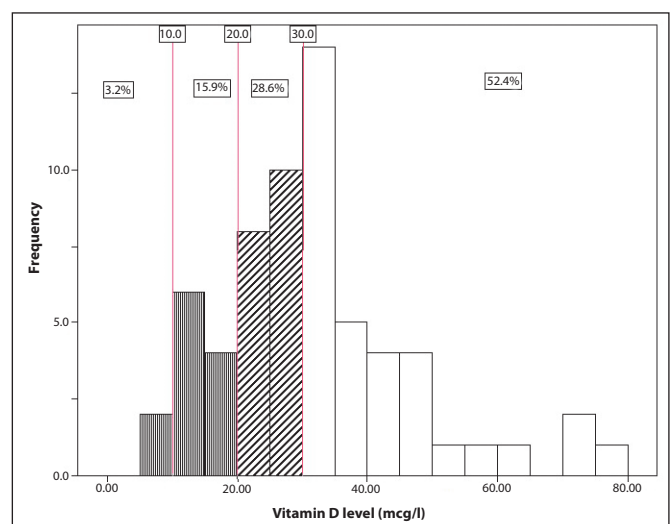
Age, sex and skin colour were recorded. Skin colour was defined as either fair-skinned (white Caucasian) or dark-skinned (Afro-Caribbean). The athlete's place of residence and training location (indoor or outdoor) for the previous 2 months were also recorded. Their competitive event was categorised as either endurance (race distances at or above 800 m) or sprint/power (all other track and field disciplines). The month of testing was recorded and categorised as either winter (December - March) or summer (April - August).

### Blood sampling

Blood samples were collected by standard venepuncture using a 10 ml syringe and 23 gauge needle. There was no standard fasting procedure before testing. For athletes tested in Birmingham (n=5) blood samples were analysed at the Birmingham Heartlands Hospital, those in Loughborough (n=17) at the Leicester Royal Infirmary and those in London (n=41) were tested at the Hospital of St John and St Elizabeth. Laboratories in London and Loughborough used the same manufacturer's chemiluminescent immunoassay (Liason, Diasorin® Dartford, Kent). No repeated sampling with the same athlete was done to compare different laboratories. The Birmingham Heartlands

**Table 1. Socio-demographics and other characteristics of the subjects**

Variable	Frequency	Percentage
Gender		
Females	31	49
Males	32	51
Endurance		
Endurance	19	30
Sprint/power	44	70
Skin		
Dark	31	49
Fair	32	51
Residence		
Japan	1	2
London	32	51
Midlands	17	27
North England	7	11
Southern Europe	2	3
Southern USA	4	6
Training environment		
Indoors	20	32
Outdoors	43	68
Month of test		
Dec	2	3
Jan	9	14
Feb	5	8
Mar	8	13
Apr	8	13
May	11	18
Jun	8	13
Jul	11	18
Aug	1	2
Season during test		
Summer	39	62
Winter	24	38



**Fig. 1. Distribution of 25(OH)D level: deficient (vertical lines); insufficient (diagonal hash); sufficient (white).**

Hospital laboratory used an HPLC tandem mass spectrometer (Applied Biosystems, Warrington Cheshire).

Insufficient 25(OH)D levels were defined as <30 mcg/l and deficiency as <20 mcg/l.<sup>10</sup>

Statistical *t*-tests were performed to assess differences between the variables noted above, under data collection, and regression analysis was used to identify independent predictors for 25(OH)D deficiency. A *p*-value of <0.05 was considered significant. The independent predictors assessed by regression analysis were location, sex, training environment, skin colour, athletic event and season of testing. The study was granted ethical approval by Queen Mary's University of London Ethics panel (QMREC2010/84).

## Results

### Demographics

Sixty-three subjects (mean ± standard deviation (SD) age 24.9±4.2 years) had their serum 25(OH)D level measured. Their socio-demographic and other characteristics are noted in Table 1. All dark-skinned athletes were Afro-Caribbean. Seventeen athletes eligible for the study did not take up the offer of the blood test.

### 25(OH)D status in elite track and field athletes

Overall analysis identified a mean (±SD) serum concentration of 25(OH)D of 31.5±15.1 mcg/l (N=63). An insufficient 25(OH)D status was noted in 29% (n=18) of athletes and a further 19% (n=12) were deficient with levels <20 mcg/l (Fig. 1).

### Risk factors for low 25(OH)D status

Female athletes, dark-skinned athletes and those tested in the winter months were all noted to have significantly lower 25(OH)D levels (Table 2). Subsequent regression analysis, on variables of sex, age, location, season, skin colour and athletic discipline, identified female sex and dark skin as independent predictors for low 25(OH)D levels.

Table 2. Differences in 25(OH)D levels by gender, event, skin colour, training venue and season		
	25(OH)D level (mean±SD), mcg/l	<i>p</i> -value
Gender		0.014
Male	36.1±15.7	
Female	26.8±13.2	
Event		0.509
Endurance	33.2±11.1	
Sprint/power	30.8±16.7	
Skin colour		<0.001
Dark	24.9±11.0	
Fair	37.9±16.0	
Training Venue		0.016
Indoors	24.2±16.6	
Outdoors	34.9±13.3	
Season		0.005
Summer	35.4±15.8	
Winter	25.2±11.8	

Analysis of the 15 dark-skinned athletes tested in the winter found 3 (20%) athletes to be insufficient and a further 8 (53%) deficient. In

the summer 7 of 16 (44%) dark-skinned athletes were insufficient and 2 (13%) were deficient (Table 3). Of the tests performed on female athletes with dark skin 54% were deficient and a further 31% had insufficient levels. There were no male athletes with fair skin noted to be deficient (Table 4).

**Table 3. Proportion of vitamin D deficient and insufficient athletes by skin colour and season**

Skin colour	Season	<i>n</i>	Insufficient, <i>n</i> (%)	Deficient, <i>n</i> (%)
Dark-skinned	Winter	15	3 (20)	8 (53)
Dark-skinned	Summer	16	2 (13)	7 (44)
Fair-skinned	Winter	9	3 (33)	
Fair-skinned	Summer	23	5 (22)	1 (4)

**Table 4. Proportion of vitamin D deficient and insufficient athletes by skin colour and gender**

Skin colour	Gender	<i>n</i>	Insufficient, <i>n</i> (%)	Deficient, <i>n</i> (%)
Dark-skinned	Female	13	4 (31)	7 (54)
Dark-skinned	Male	18	6 (33)	3 (17)
Fair-skinned	Female	18	5 (28)	2 (11)
Fair-skinned	Male	14	2 (14)	0 (0)

## Discussion

This is the largest published study on 25(OH)D levels in elite international athletes. It provides clear evidence of a notable prevalence of 25(OH)D insufficiency and deficiency in elite UK track and field athletes. It should be recognised that this study is an observational cross-sectional study in our elite athlete group and there are no control group data from non-elite athletes or the general population. However, the aim of the study was to determine the prevalence of 25(OH)D deficiency in athletes. Two differing laboratory techniques were used to determine 25(OH)D levels with the resultant possibility of inter-laboratory variability. There were no significant differences between the mean 25(OH)D levels in the groups assessed by each laboratory.

The prevalence rates reported here support those of previous studies in young adults.<sup>17,39</sup> In the USA and Canada 36% of young adults have been noted to be deficient in the winter,<sup>39</sup> which compares with our winter figure of 38%. Our overall prevalence of deficiency throughout the year of 19%, with insufficiency in a further 28%, is similar to published work relating to adolescents in northern USA (latitude 42°N) which noted 24% of subjects with levels <15 mcg/l.<sup>17</sup> By comparison, in Middle Eastern national level athletes from a variety of sports, 93% of athletes were noted to be deficient and, in Australia, 33% of 18 gymnasts were found to be deficient.<sup>18,19</sup>

In our cohort, skin colour and sex were noted to be significant independent predictors of vitamin D status. The remarkable prevalence of deficiency in 54% of dark-skinned female athletes (and insufficient levels in a further 31%) is still comparable with some published literature in older groups of a similar skin colour.<sup>29</sup> Skin colour is well recognised as a predictor of vitamin D status with numerous studies identifying lower levels in individuals with dark skin.<sup>29-31</sup> This is primarily due to increased melanin content reducing UVB absorption and subsequent vitamin D production.<sup>32</sup> It has also been reported that seasonal

differences in 25(OH)D levels, while apparent in other populations, is less evident in dark-skinned individuals.<sup>40</sup> This is supported by our study, which found that season was not an independent predictor and prevalence of deficiency and insufficiency were similar in the dark-skinned group throughout the year, presumably because of persisting reduction in cutaneous production.

However, in addition to melanin content, social behaviour such as sun exposure and clothing should also be considered when reviewing an athlete's risk of developing vitamin D deficiency. In studies of Middle Eastern groups, females have been reported to have significantly lower 25(OH)D levels.<sup>41-43</sup> This has been attributed to required clothing covering all skin and thereby reducing exposure to UVB.<sup>44</sup>

In South Africa, the Mediterranean and other sun-rich areas the relevance of this study may not be immediately apparent. While individuals in sun-rich areas may be at less risk,<sup>45</sup> a number of studies have shown a significant prevalence of vitamin D deficiency in these areas,<sup>46,47</sup> potentially due to an individual's skin colour or sunscreen application. Our study findings would support the assertion that clinicians in any geographical area with a significant population of dark-skinned individuals should be mindful of the possibility of vitamin D deficiency.

Sex was a significant independent predictor in our study and this has been noted in other populations.<sup>48</sup> It is possible that the application of sunscreen, UVB-blocking moisturiser or make-up may enhance the risk of developing deficiency. Unfortunately we do not have information on hours of sun exposure or the use of sun-protection agents; further work is required. However, if these findings were corroborated in a larger athlete group, vitamin D deficiency may be an additional aetiological risk factor for the increased incidence of stress fractures in female athletes.<sup>49-54</sup>

Insufficient serum concentration of 25(OH)D is known to increase parathyroid hormone (PTH) secretion, increasing bone turnover and bone resorption.<sup>55</sup> In a prospective study, in Finnish army recruits, high serum PTH levels were identified as a risk factor for stress fracture development.<sup>56</sup> In two studies lower 25(OH)D levels have been found to be associated with a significantly increased risk of stress fracture in young Finnish men<sup>57</sup> and with high-grade stress fractures, in a large army cohort.<sup>58</sup> One randomised controlled trial of more than 5 000 army recruits reports a reduction in stress fractures after daily supplementation of 2 g calcium and 800 IU vitamin D.<sup>59</sup>

In addition to the classic role in bone metabolism, vitamin D deficiency may directly impact on athletic performance through other physiological mechanisms including muscle function,<sup>38,60-62</sup> immunity and the potential mediation of exercise-induced inflammation.<sup>63,64</sup> The vitamin D receptor and intracellular vitamin D regulation have also been identified in heart muscle, liver, lung and adrenal systems, all of which are determinants of athletic performance.<sup>13,65,66</sup>

However, the direct evidence for treatment of vitamin D deficiency to improve performance is extremely weak. High-quality trials in athletic populations are required to determine the effects of correcting vitamin D deficiency and insufficiency on athletic, and particularly muscular, performance. There remain many questions regarding optimal 25(OH)D serum concentration and management of deficiency in athletes, and indeed the wider population. Management may include increased sunlight exposure, dietary fortification and medication such as cholecalciferol. However, as this study reveals, athletes are at risk of 25(OH)D deficiency and, for the reasons discussed above, we recommend that sport and exercise medicine physicians are mindful of assessing vitamin D status.

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